Comparative Study of Sand Control Methods in Niger Delta

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***Abstract*- Sand production like water and gas production is one of the perennial problems plaguing the oil industry because of its safety, economics or environmental impact on production. In order to properly optimise production and monitor sand controlled well, it is imperative to evaluate the well performance, sand control effectiveness and durability of the treatment type installed in order to achieve the main aim of hydrocarbon production. The principal methods of sand control that are available to oil industry in Nigeria are internal gravel pack (IGP) and sand control using chemicals (SCON). This paper compares the principal methods of sand control measures installed in terms of their effect on performance, durability and sand control effectiveness in Niger Delta. Production and well data from 10 different wells were gotten for their flow rate, sand production and water production. Actual and ideal productivity index are calculated. Well inflow quality indicator (WIQI) was used as a criteria to determine the performance of the well for their treatment types. A graph of the production data was plotted against time (years). A bar chart of the treatment type before installation is plotted against time (years) and also a bar chart of sand produced after the treatment type installed was made to determine the durability and sand production effectiveness of the treatment types installed. The result show that SCON wells have better performance than IGP wells with WIQI values ranges from 0.6 – 1 to that of 0.2 – 0.6 for IGP wells. SCON wells recorded 2-4 years to that of 6 – 12 years of IGP wells for durability. SCON wells recorded sand production of about 55Ib/1000bbl, to that of 34Ib/1000bbl, for IGP wells after their installations. Based on these findings IGP wells are recommended for Niger Delta formation.**

Keywords- Reservoir; Sand Control; IGP; SCON; Niger Delta; WIQI

I. INTRODUCTION

Sand production (or sanding) is the production of the formation sand alongside with the formation fluids (gas, oil and water) due to the unconsolidated nature of the formation. Produced sand has essentially no economic value. On the contrary, formation sand do not only plug wells to reduce recovery rates, it also erode equipment and settle in surface vessels. Controlling formation sand is costly and usually involves either slowing the production rate or using gravel packing or sand-consolidation techniques. As a result of this, sand production is a major issue during oil and gas production from unconsolidated reservoirs. Its effect is a peculiar problem of the Niger Delta oil province which describes the Niger Delta as complex and its geology. The production of sand is a worldwide problem. Areas of major problems include the U.S Gulf Coast, California, Canada, China, Venezuela, Trinidad, Western Africa, and Indonesia. At least some problems are reported in all areas of the world where oil and gas are produced. Sand production is initiated when the formation stress exceed the strength of the formation [1, 2]. The formation strength is derived mainly from the natural material that cements the sand grains, but the sand grains are also held together by cohesive forces resulting from immovable formation water (residual water). The stress on the formation sand grains is caused by many factors notably; tectonic actions, overburden pressures, pore-pressures, stress changes from drilling, and drag forces on producing fluids. In some cases, the onset of sand production occurs late in the life of a field when pressure have declined to the extent that the overburden is being supported mainly by the vertical component of inter grain stress rather than by the pore pressure [3]. This may cause shearing of the cementing material allowing the sand grains to move and hence be produced into the wellbore or, below a certain pore pressure, the point stress between the sand grains exceeds their fracture strength and the grains collapses causing instability and onset of sand production.

Sand production is one of the oldest problems of oil field. It is usually associated with shallow formations as compaction tends to increase with depth. But in some areas, sand production may be encountered to a depth of 12,000ft or more. Sand production higher than 0.1% (volumetric) can usually be considered as excessive, but depending on the circumstances, the practical limit could be much lower or higher.

Several factors are responsible for the production of sand oil and Gas wells in Niger Delta area of Nigeria. Firstly, by virtue of the considerable porosity of the Niger Delta, reservoir sands tend to be weakly consolidated or totally unconsolidated and are thus produced when the well flows. The unconsolidated sands are loose and are susceptible to being produced into the wellbore and to the surface unlike the consolidated (compacted) sands that are carried by fluid drag force. Secondly, the rate at which the formation is produced can lead to sand production in a well. Every reservoir has a threshold pressure, which is the pressure at which a well will produce sand free. But this threshold pressure is below economic producing rate; therefore, the engineer tends to ignore the threshold pressure so as to produce at a maximum rate from a sand stone reservoir, sand will be produced. Thirdly, when the wellbore pressure is small compared to the reservoir pressure, this will lead to high rate of fluid flow from the reservoir into the wellbore. The high viscosity fluid that flows with high velocity from the reservoir into the wellbore may be produced with the reservoir sand. Fourthly,

in Nigeria, hydrocarbon bearing reservoirs are characterized by relatively thin sand with broken shale that breaks and are mostly unconsolidated often due to high permeability and porosity. By virtue of the unconsolidation of the sands, they are produced into the well when the well flows if not properly controlled. And finally, a reservoir that might have been certified sand free may begin to produce sand after a long time because a lot of factors changes with time. Some of these changes could be reservoir depletion, water production and increased overburden stress.

The general sand production can be classified into three categories: transient, continuous and catastrophic. The transient sand production is commonly encountered during clean-up after perforation or acidizing. At this stage, sand production will decline with time. The continuous sand production occurs during production from unconsolidated sandstone reservoir that has no sand control equipment. For this case, sand production is observed throughout the life of the well. The catastrophic sand production refers to events where a high rate of sand influx causes the well to die and/or choke. This occurs when the reservoir fluids are excessively produced and this is the worst case of sand production.

The production of formation sand with the oil and gas from the sand prone formation creates a number of potentially dangerous and costly problems. These effects are summarised in Table 1 below.

TABLE I EFFECTS OF SAND PRODUCTION

Area	Problem	Effect
Reservoir	Wellbore fill	• Restricted access to production interval • Loss of productivity • Loss of reserve
Subsurface Equipment	Sand fouling	• SSSV not operating • Difficult wire line operation
	Erosion	• Equipment replacement • Equipment failure.
Surface installation	Sand accumulation	• Malfunctioning of control equipment • Unscheduled shut down
	Erosion	• Deferred production • Sand separation and disposal

Whatever sand exclusion method that is adapted, it cannot be guaranteed that they will work indefinitely. Consequently, it is essential that the sand content of the produced fluids be monitored so that if a well starts producing sand it can be shut-in before subsurface or surface equipment becomes blocked or damaged. The methods of monitoring sand production can be batch, probe or downhole sand detection. The batch monitoring system is the cheapest method of sand monitoring. It involves periodically taking a sample of produced fluid from the well head, filtering out and washing the sand, drying it and weighing it [4, 5]. Unfortunately, this method can be inaccurate because of the random nature of sand production, particularly if the well is slugging or on intermitted pump. However, if a greater weight of sand is collected over a longer sampling period after passing a known quantity of produced fluid through a filter, better accuracy may be obtained. The probe monitoring involves a continual monitoring and leads to a greater accuracy than periodic observation. Sand probes may be used to shut in a well or to monitor and record the quantity of sand produced [5]. These probes can be mechanical probe, sonic probe or piezo-electric probe. The downhole sand detection uses a system known as SANFLOG, which operates on the same principle as the SAFLO detector [5] to detect sand influx in a dry or wet gas wells or single liquid phase wells. The system can also be used as a listening device operating on audio signals between 0.3 and 10 KHz [6]. This dual capability allows the operator to use the tool to listen for flow from producing interval while simultaneously recording sand impacts. If only part of the producing formation is contributing to sand production, the operator may elect to selectively treating the specific zone.

The methods/techniques that is being used to control sand in formations producing sand can be grouped as mechanical, chemical or combination methods. The mechanical exclusion of sand is effected by setting up a physical barrier to the sand movement, which still allows for the passage of reservoir fluids. The barrier takes the form of a screen surrounded by fine gravel, which is sized so that the formation sand cannot pass through the pore throats of the gravel. As such, the mechanical exclusion of sand is based upon the relationship between the size of the formation sand, the gravel, and the screen slot widths. This is achieved through Gravel packing (open hole and cased Hole), Frac Packs, Stand-alone screen, Wire wrapped screen, and Expandable sand screen method. The chemical control method involves the injection of chemicals usually resin into the formation through perforations to cement the sand grains. The most commercially available systems employ resins are phenolic, furan and epoxy resins [3,7]. These chemicals bind the rock particles together creating a stable matrix of permeable, consolidated grains around the casing. Clay concentration can hinder the effectiveness of the consolidation process, so a clay stabilizer is often used as a pre-flush. The sand consolidation process relies on a process comprising of four distinct stages: Placement of resin in the formation using a carrier fluid; Separation of the resin from the carrier fluid; accumulation of the resin around the grain contact points; Curing of the resin. In addition to the mechanical and chemical sand control methods, several combinations of sand-control techniques that use both gravel and plastic have been employed. The aim is to consolidate the gravel pack after it is placed but without the use of a screen or slotted liner. The *epoxy* and *furan* techniques involve resin-coated gravel mixed at the surface and pumped into the well. The gravel plastic slurry is then allowed to settle and cure. After curing, the residue is drilled out of the well before it is placed on production. The phenolic resin-coated gravel processes involve phenolic-coated gravel that is partially polymerized. Upon being subjected to temperatures higher than 57°C, the resin cure is completed so that the gravel is consolidated. Unlike the *epoxy* and *furan* processes, the phenolic resin-coated gravel is dry and can be handled much like ordinary gravel.

This paper evaluates the performance of two chemical sand control methods; sand consolidation (SCON) and internal gravel packing (IGP). The durability and effectiveness of the sand control methods are also compared.

II. METHODOLOGY

The comparative study of the sand control methods is based on the performance, durability and sand control effectiveness of the treatment type used in a well. The treatment type that is been evaluated in this paper is sand control using chemical (SCON) and internal gravel packing (IGP). The comparative study of this treatment type is carried out on Niger Delta wells. Production data for oil production (b/d), sand production (Ib/1000bbl) and water production (%) of different wells that sand control job has been carried out are listed.

A. Performance of the Sand Control Methods

Well inflow quality indicator (WIQI) is the criteria used to determine the performance of the treatment types. It is the ratio of the actual productivity index (PI_{actual}) to the ideal productivity index (PI_{ideal}) assuming no impairment or formation damage for a given draw down.

$$WIQI = \frac{PI_{actual}}{PI_{ideal}} \tag{1}$$

Skin was not included in this WIQI correlation due to time constrain and lack of data.

Thus, WIQI ≤ 1; this indicates that when the WIQI is closer or equal to 1, the better the performance of the well. However,

$$PI_{actual} = \frac{q}{\Delta P} \tag{2}$$

$$PI_{actual} = \frac{q}{Pr - Pwf} \tag{3}$$

This q is the average flow rate after the sand control job has been carried out.

PI_{ideal} is calculated using this equation:

$$PI_{ideal} = \frac{7.08E{-}3 \times ko \times h}{\mu o \times Bo \times In(\frac{re}{rw})} \tag{4}$$

B. Durability of the Sand Control Methods

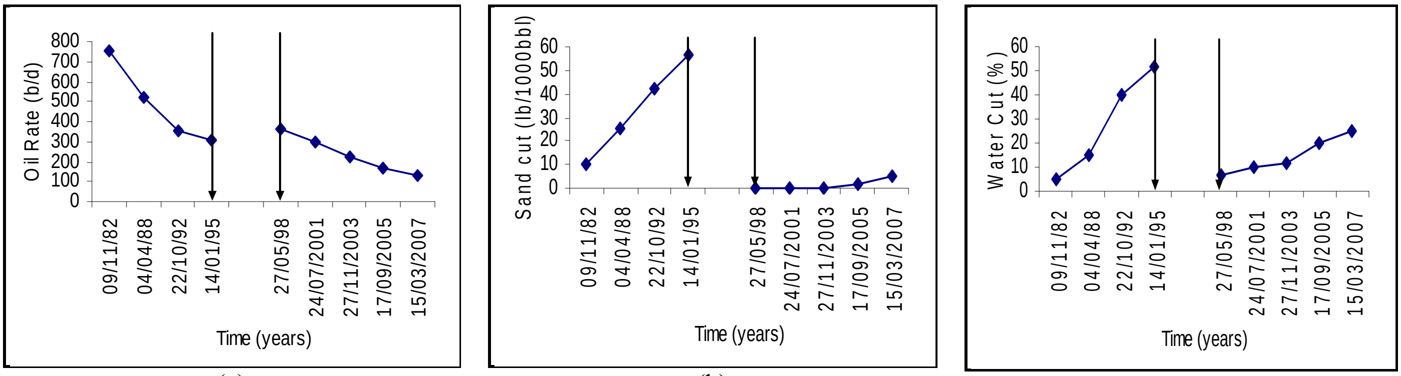
A graph of sand production (Ib/1000bbl) is plotted against time (in years). From this graph, a bar chart is made for time versus treatment type after the job to know which of the treatment type is more durable.

C. Effectiveness of the Sand Control Methods

A bar chart of sand produced (Ib/1000bbl) after instalment of treatment type versus time is made to know the effectiveness of the treatment types.

III. RESULTS

The production data of all the 10 wells for oil, sand and water production are shown in figure 1 to 10 below.



(a) (b) (c)

Fig. 1. Well 1 (a) Oil production rates, (b) Sand cut Production and (c) Water cut Production in years

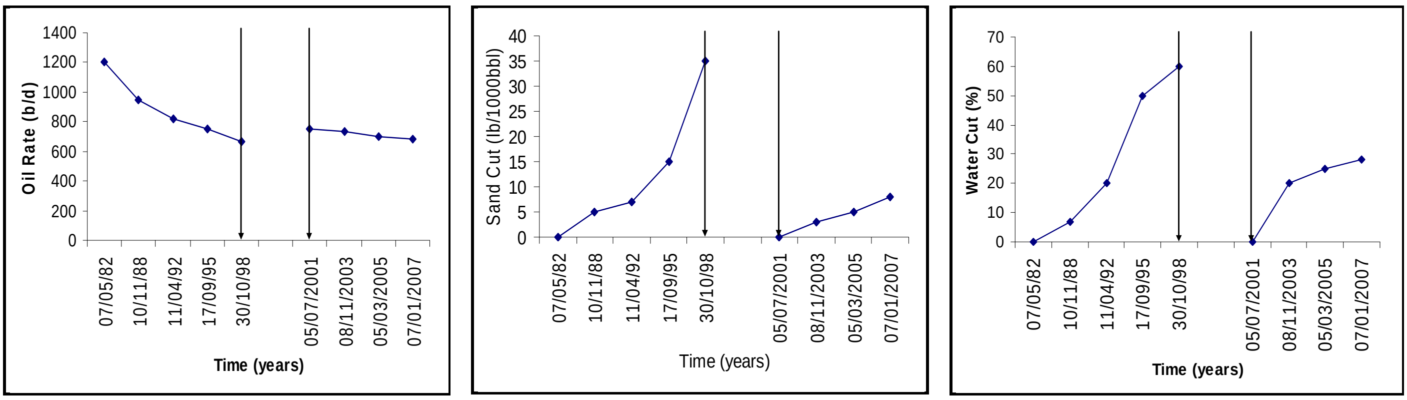


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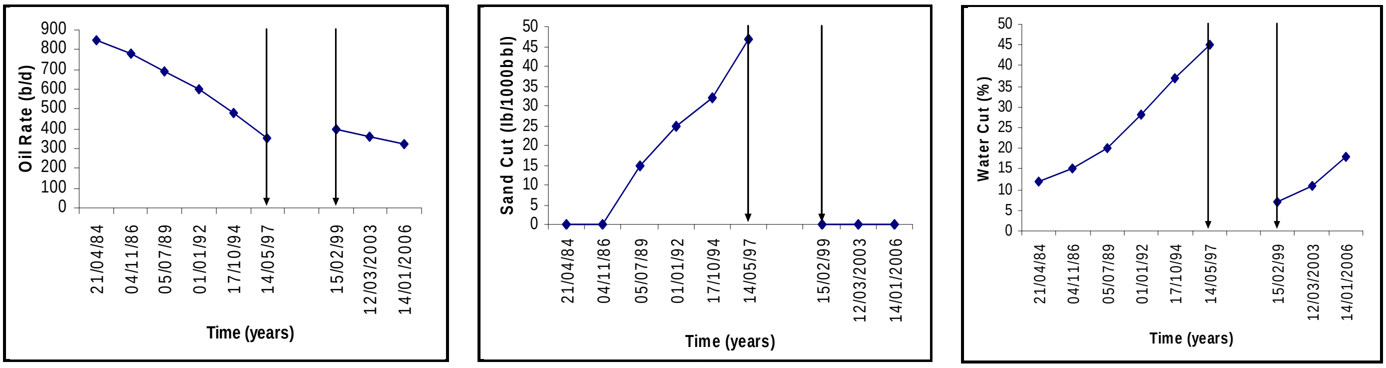
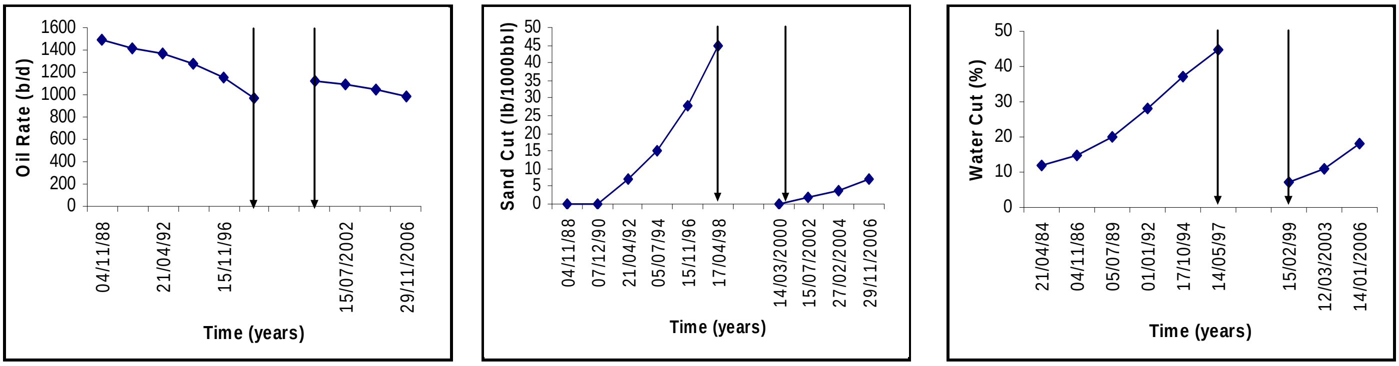
Fig. 2. Well 2 (a) Oil production rates, (b) Sand cut Production and (c) Water cut Production in years



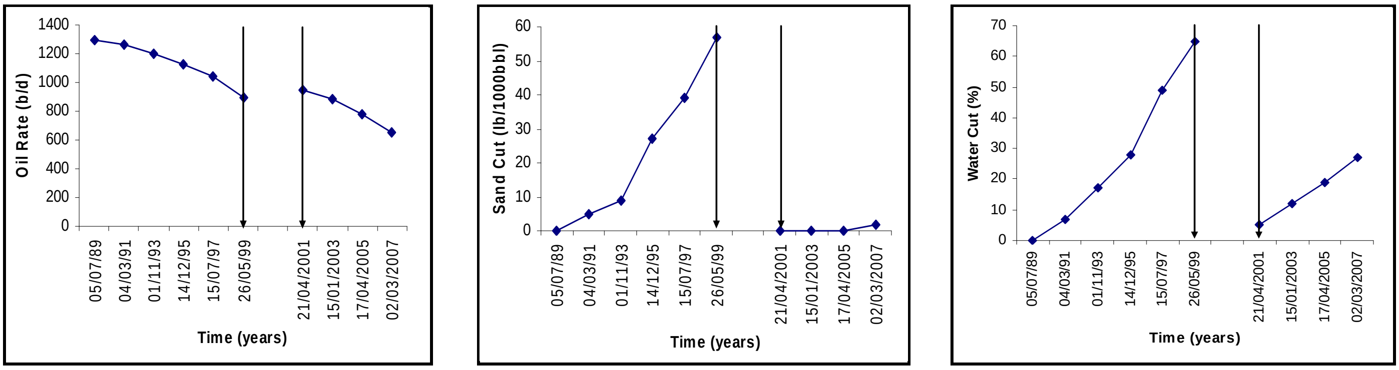
(a) (b) (c)

Fig. 3 Well 3 (a) Oil production rates, (b) Sand cut Production and (c) Water cut Production in years



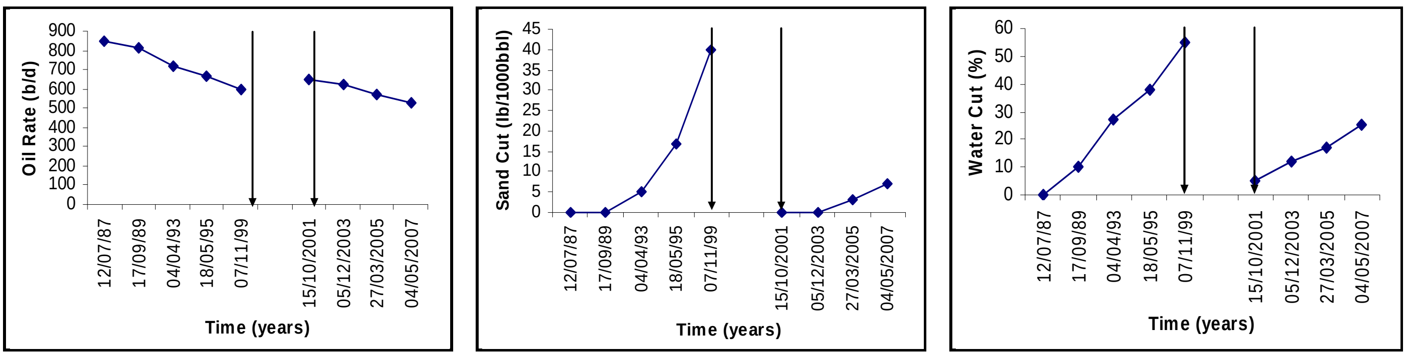
(a) (b) (c)

Fig. 4 Well 4 (a) Oil production rates, (b) Sand cut Production and (c) Water cut Production in years



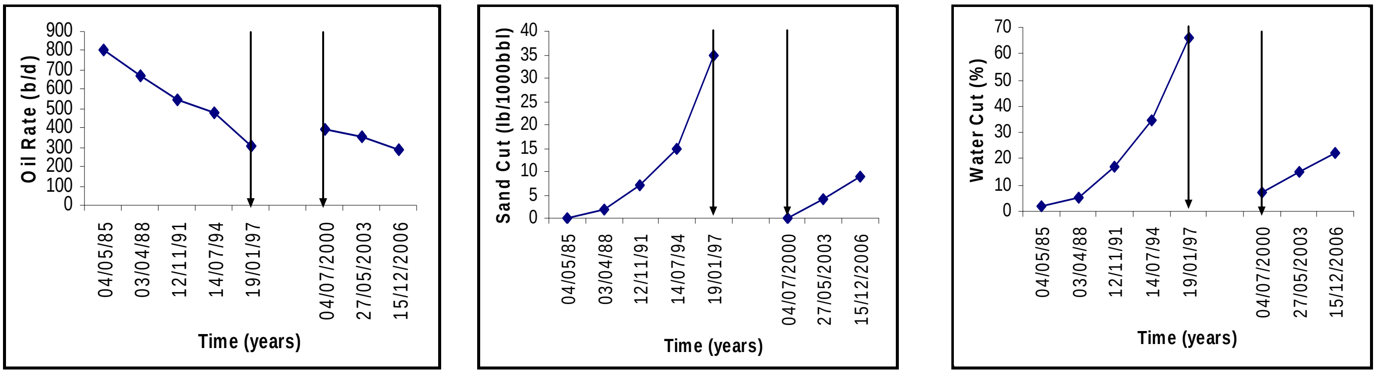
(a) (b) (c)

Fig. 5 Well 5 (a) Oil production rates, (b) Sand cut Production and (c) Water cut Production in years



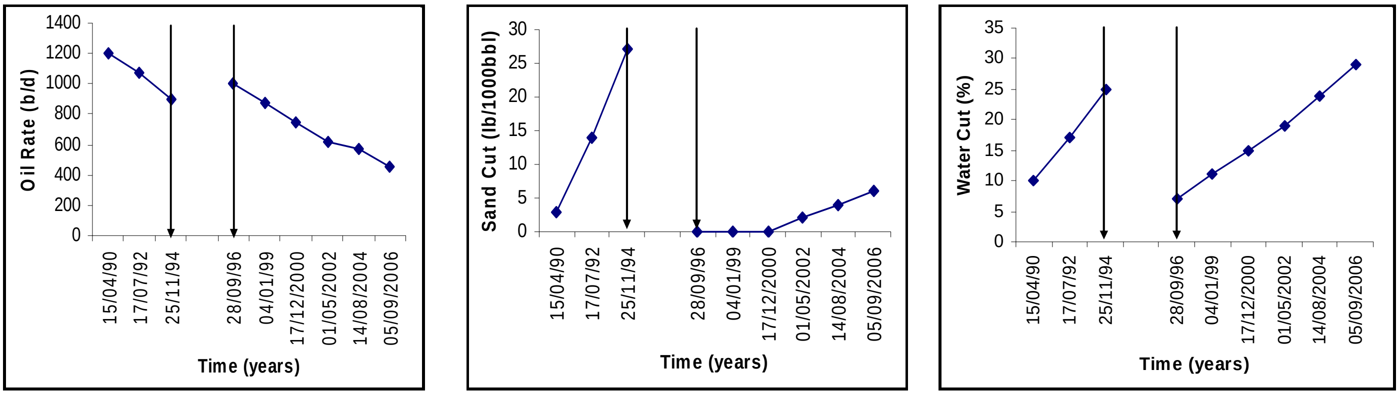
(a) (b) (c)

Fig. 6 Well 6 (a) Oil production rates, (b) Sand cut Production and (c) Water cut Production in years



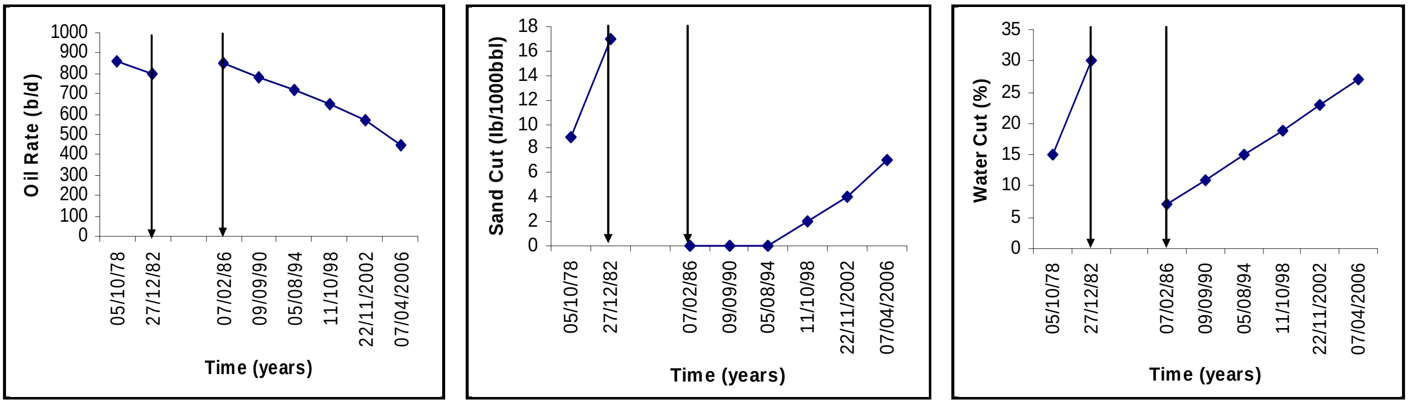
(a) (b) (c)

Fig. 7 Well 7 (a) Oil production rates, (b) Sand cut Production and (c) Water cut Production in years



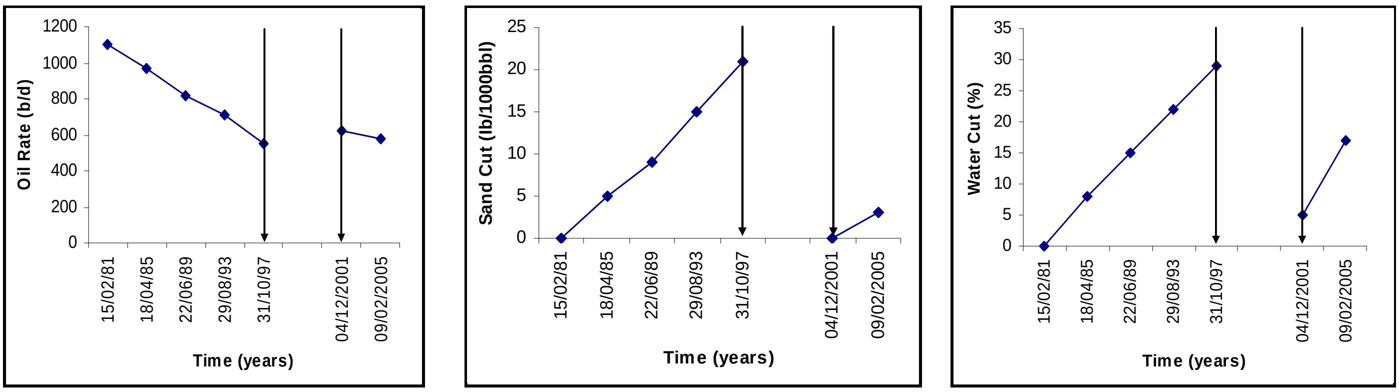
(a) (b) (c)

Fig. 8 Well 8 (a) Oil production rates, (b) Sand cut Production and (c) Water cut Production in years



(a) (b) (c)

Fig. 9 Well 9 (a) Oil production rates, (b) Sand cut Production and (c) Water cut Production in years



(a) (b) (c)

Fig. 10 Well 10 (a) Oil production rates, (b) Sand cut Production and (c) Water cut Production in years

IV. RESULTS ANALYSIS

From Figure 1 to Figure 10 and Equation 1 to Equation 4 above, the value of WIQI was calculated to determine the performance of the control methods used. Further analyses are carried out to determine the effective and durability of the sand control method used.

A. Performance of the Sand Control Methods

Individual sand controlled well data are collected to enable the PI_{ideal} and PI_{actual} to be calculated. PI_{actual} data source is from BHP survey which is the reservoir pressure (P_r), flowing well pressure (P_{wf}) and oil production rate (q), which is the average oil production after the sand controlled mechanism has been installed. The data used for each well are shown below. The well inflow quality indicator (WIQI) which is the parameter used to determine the performance of the treatment types for each well are calculated using the data below and the values tabulated in Table 2. Figure 11 shows the pie chart for the percentage WIQI for each treatment methods from all the wells.

Well 1: r_e = 1500ft, r_w = 0.4ft, K_o = 1000md, H = 10ft, μ_o = 2.5cp, B_o = 1.5rb/stb, P_r = 3000psi, and P_{wf} = 2803psi.

Well 2: r_e = 1500ft, r_w = 0.4ft, K_o = 1000md, h = 15ft, μ_o = 2cp, B_o = 1.5rb/stb, P_r = 3000psi, and P_{wf} = 2810psi.

Well 3: r_e = 1500ft, r_w = 0.7ft, k_o = 900md, h = 14ft, μ_o = 1.5ft, B_o = 1.3rb/stb, P_r = 3200pis, and P_{wf} = 3100psi.

Well 4: r_e = 1500ft, r_w = 0.5ft, K_o = 1100md, h = 12ft, μ_o = 3.5cp, B_o = 1.7rb/stb, P_r = 2800pis, and P_{wf} = 2212psi.

Well 5: r_e = 1500ft, r_w = 0.45ft, K_o = 1200md, h = 11ft, μ_o = 2.7cp, B_o = 1.6rb/stb, P_r = 2900psi, and P_{wf} = 2330psi.

Well 6: r_e = 1500ft, r_w = 0.3ft, K_o = 900md, h = 8ft, μ_o = 1.5cp, B_o = 1.5rb/stb, P_r = 2850psi, and P_{wf} = 2537psi.

Well 7: r_e = 1500ftg, r_w = 0.4ft, K_o = 1300md, h = 9ft, μ_o = 1.5cp, B_o = 1.8rb/stb, P_r = 2800psi, and P_{wf} = 2646psi.

Well 8: r_e = 1500ft, r_w = 0.5ft, K_o = 1300md, h = 22ft, μ_o = 1.5cp, B_o = 1.1rb/stb, P_r = 3500psi, and P_{wf} = 3299psi.

Well 9: r_e = 1500ft, rw = 0.5ft, K_o = 1200md, h = 20ft, µo = 1.7cp, Bo = 1.2rb/stb, Pr = 3300psi and P_{wf} = 3085psi.

Well 10: r_e = 1500ft, r_w = 0.4ft, K_o = 1350md, h = 7ft, μ_o = 1.7cp, B_o = 1.5rb/stb, P_r = 3000psi and P_{wf} = 2806psi.

TABLE II TREATMENT TYPE AND THEIR WIQI

Well No.	Treatment Type	PI_{actual} (bbl/d/psi)	PI_{ideal} (bbl/d/psi)	WIQI
1	IGP	1.20	2.30	0.52
2	SCON	3.76	4.30	0.87
3	IGP	3.60	6.00	0.60
4	SCON	1.80	2.00	0.90
5	IGP	1.43	2.70	0.53
6	SCON	1.89	2.70	0.70
7	SCON	2.23	3.73	0.60
8	IGP	3.53	15.33	0.23
9	IGP	3.12	10.40	0.30
10	SCON	3.09	3.19	0.97

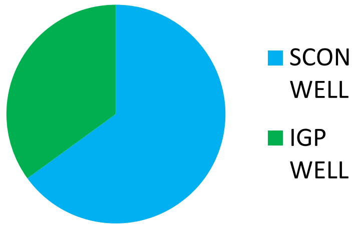


Fig. 11 A Pie Chart of WIQI for treatment types

B. Effectiveness of the Sand Control Method

A bar chart for sand production against the treatment type is made from Table 3 to know the effectiveness of the treatment types. Figure 12 shows the bar chart of sand produced after the installation of the treatment type.

TABLE III SAND PRODUCED AFTER APPLICATION OF IGP OR SCON

Well No	Treatment Type	Sand Produced (Ib/1000bbl)
1	IGP	7
2	SCON	16
3	IGP	0
4	SCON	13
5	IGP	2
6	SCON	10
7	SCON	13
8	IGP	12
9	IGP	13
10	SCON	3

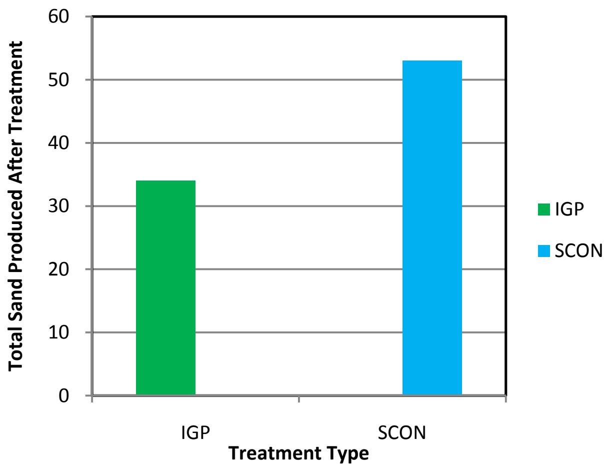


Fig. 12 Bar Chart of Sand Produced after the Job

C. Durability of the Sand Control Methods

The durability of the sand control method is based on the duration in years before the well start producing sand.

TABLE IV DURATION BEFORE THE WELL STARTS PRODUCING SAND AFTER THE SAND CONTROL JOB

WELL NO	Treatment Type	Before Sand Was Produced	Sand Production Begins	Duration (Yrs)
1	IGP	1998	2005	7
2	SCON	2001	2003	2
3	IGP	1999	2006	7
4	SCON	2000	2002	2
5	IGP	2001	2005	6
6	SCON	2001	2005	4
7	SCON	2000	2003	3
8	IGP	1996	2002	6
9	IGP	1986	1998	12
10	SCON	2001	2005	4

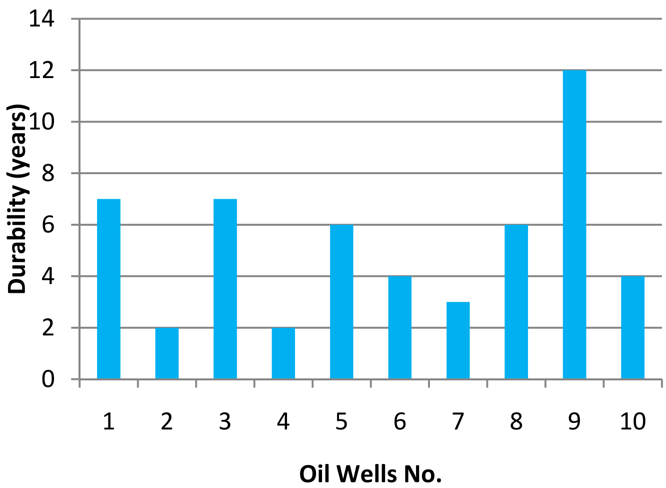


Fig. 13 Bar Chart of treatment type vs. Duration in years

V. DISCUSSION

From table 2; IGP wells have ranges of WIQI from 0.2-0.6 and SCON have ranges of 0.6-1.0. From fig 11, wells that are treated with SCON recorded a WIQI success of 65% and those treated with IGP recorded 35% success. The decrease in IGP well performance may be due to debris and loose sand from the formation during production which plugs the pore spaces in the gravel pack. It can also be caused by unclean completion fluid which causes contamination, wrong gravel size selection, wrong selection of screen slot to retain the gravel and ineffective placement technique. From fig. 12; after the sand control job have been done, wells that are sand controlled using SCON technique tend to produce more sand when the mechanism starts to be weak compared to wells that are installed with IGP. Thus, SCON recorded 55Ib/1000bbl to IGP which is 43Ib/1000bbl. This might be caused by the weakness of the chemical used for the job because during production, the producing fluid tends to wash away the chemical used which will reduce the effectiveness of the SCON well. From fig 4.3; wells that are installed with IGP last longer than wells that are installed with SCON. IGP last about 6-12 years after the mechanism have been installed to that installed with SCON which is about 2-4 years. This might be due to high temperature in the subsurface which reduces the consolidation of the sand as time goes on which thus reduces the durability of the SCON installed well.

VI. CONCLUSION

Based on the findings of this comparative study of sand control using SCON and IGP, their performance, durability and sand control effectiveness, the following conclusions were made:

- Wells that are sand controlled using SCON have high WIQI values than that of IGP.
- The values of WIQI for SCON and IGP controlled wells have WIQI values ranging from 0.6 -1.0 and 0.2- 0.6.respectively.
- Wells installed with IGP are more durable than that of SCON wells.
- It took IGP wells a period of 6 - 12 years and SCON wells a period of 2 - 4 years before sand is being produced from the wells.
- Wells that are sand consolidated (SCON) produces more sand when the mechanism gets weak than wells that are gravel packed (IGP).
- SCON wells produces 55Ib/1000bbl of sand when the mechanism becomes weak to that of IGP wells which is 43Ib/1000bbl.
- Consequently, SCON should be installed when the interval is less than or equal to 10ft and IGP should be installed when the interval is greater than or equal 10ft. Thus, this paper also recommend that IGP wells are more durable and effective than SCON wells while SCON wells have better performance than that of IGP wells. Hence, IGP is recommended for Niger Delta formation.

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